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Energy Procedia 115 (2017) 162–172

Energy Procedia

www.elsevier.com/locate/procedia

International Conference – Alternative and Renewable Energy Quest, AREQ 2017, 1-3 February 2017, Spain

The Impact of Window Configuration on the Overall Building Energy Consumption under Specific Climate Conditions

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Abstract

The present research investigates the effect of orientation and façades openness and glazing type on global energy consumption in typical offices under the specific climate of present areas in the south of Algeria using Eneryplus software version (8.4.0), a serie of simulations has been performed in order to establish the optimal window configuration in terms of area orientation and glazing type .

Key words: Energy consumption; sustainable development ; Energy plus; opening ; Ratio (window, wall); Orientation; glazing Type.
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1. Introduction

Buildings consume about 40%of the world's energy [1], the use of electric power and heat in the building sector also participate at gaz emissions, sustainability with efficient energy use and minimal environmental impact has become a major building design goal.

Façade openings configuration have a great impact on the overall energy consumption of a building as it represents the most energy sensitive part of building envelope.

The use of large glazing openings in present areas has become an accepted architectural trends in Algeria without any knowledge of their drastic effects on building energy performance.

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1876-6102
10.1016/j.egypro.2017.05.016

The article analyses different window configuration on space user comfort and energy consumption in office building in Biskra (Algeria) using parametric window design alternatives.

2. Role of windows

The window is considered the weakest thermal link in a building envelope for heat gain in summer and heat loss in winter. Although it presents a small area of the building, it has the greatest effect on heat flow than walls, ceilings, and floors of the building. Therefore, it is considered as one of the important elements that affect the building energy consumption [2].

In general, the thermal performance of a window can be basically specified by three factors, which are the thermal transmittance (U-value), total solar energy transmittance (g-value), and air leakage (L). These factors describe all amounts of heat flow through a window [3].

Windows are also responsible for about 25-30% of the heat loss in a building because window glazing is a poor insulator [4]. Besides shading devices there are three parameters that determine the amount of heat gain and heat loss through windows, which are the window to wall area ratio (WWR), the window orientation, and the thermal properties of glass material [5]. This research focuses on these parameters to design windows according to heating and cooling requirements in winter and summer, under the specific climate conditions of desert area.

3. Building energy modeling

In the first decades of the twenty-first century , the wide availability of powerful scaled computers with sufficient strong and graphic capabilities have enabled of transition in the fundamental means of building representation from two dimensional drawings as diagrams of design to three dimensional, behaviorally dynamic digital prototypes.

Among the tools available to architects, designers, and engineers in the study of energy-related behaviors, energy simulation software is the most efficient. Through creating a virtual building environment, these software packages provide for the expert the opportunity to predict the actual performance of the building as well as optimize and improve its design and make use of new energy-efficient technologies for it [6].

Building energy modeling (BEM) is a representation of energy performance within a building user simulation.

Since simulation isolates a small range or one building feature for evaluation, it allows design analysis to objectively identify the right building element of energy- saving measure from analysis of the result isolating an energy –saving feature prioritizes a specific design objective.

In the present case openings orientation of a basic office on the site during conceptual design will determine which energy –saving measure is most critical.

3.1. Case study modeling and climate conditions

To study and test the research variables, we must first introduce a model or sample as the main research basis so that the behavior/effects of the research variables can be compared with it [7].
A typical office building block given in figure1 is considered for simulation. It is composed of six offices and circulation area15% of the surface area, the block is shadowed by neighboring building of the same height.

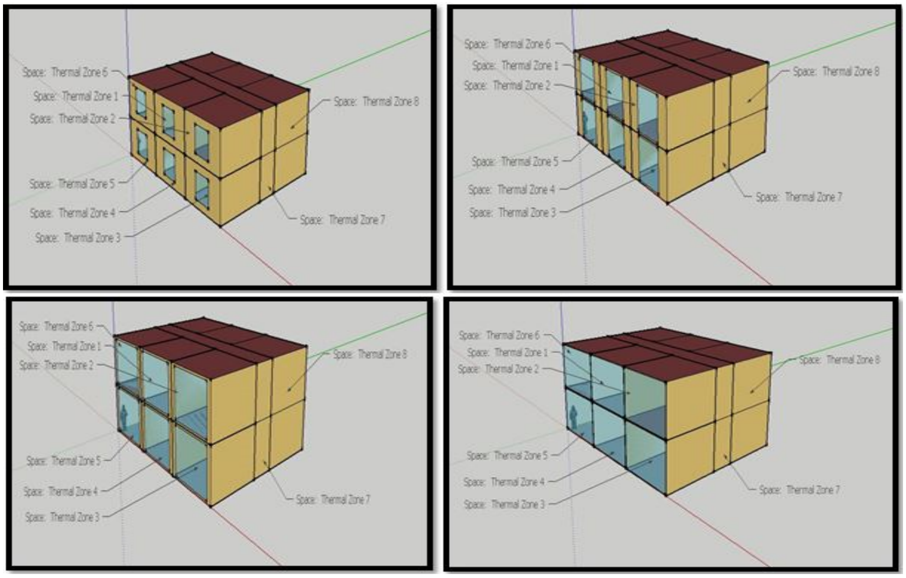


Fig1: Case study modeling. Source : Author.

The characteristics of the present model are given in table1.

The constant parameters	Variant parameters
Site: the city of Biskra (latitude 34.48 N, longitude 5.44N).	Glazing type
The area: Urban.	Ratio (25%, 50%, 75%, 100%)
- The geometry:	Orientation (North, East, South and West)
- Exterior wall :(coated cement, brick 15cm, air blade, brick 10cm, plaster coating)	
-Interior wall: (plaster coating, brick 10cm, plaster coating)	
-Slab: (pierre, floating slab, cement mortar, tiling)	
-Interior slab: (plaster coating, hollow body, compression slab, cement mortar, tiling)	
-Floor: (plaster coating, hollow body, compression slab, bastard mortar, sand, bastard mortar, gravel)	
- windows (single glazing)	

Table1: Model characteristics. (Source: Author).

The site location is considered to be in Biskra. The city of Biskra is a Saharan town located in the south-east of

Algeria; it occupies an area of 21,671 Km^2. It is characterized by a cold climate in winter, hot and dry in summer. The geographical characteristics of the city are:
- The latitude = 34.48 N.
- Longitude = 5.44 N.
- The altitude which is equal to 128 m above sea level.

The city of Biskra is characterized by a maximum temperature in summer which reaches 45 ° C in July and a minimum temperature in winter reaching 5 ° C during the month of January [1].

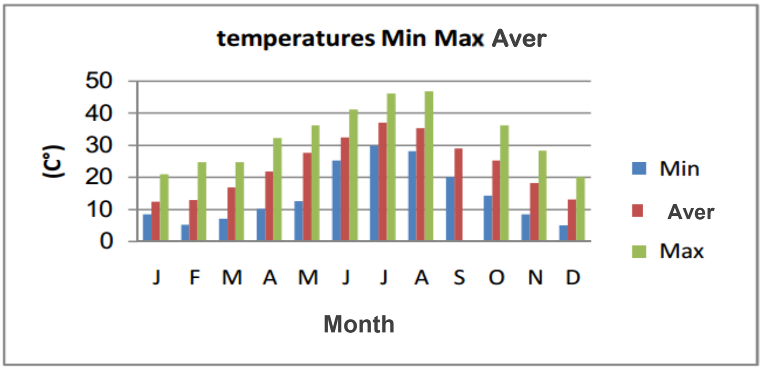


Fig2: Minimum, maximum and average temperatures of
The city of Biskra. (Source: N R H, Biskra, 2002).

4. Simulation tools

4.1. The Energy Plus software

The energy plus software is born from two software BLAST (Building Loads Analysis and System thermodynamics and DOE-2 which have been used since the end of 1970 [8].
Energy plus is an energy and thermal simulation tool and is easily accessible by the designer to use the great potential of comparative studies of parametric type.

4.2. Modeling conception and construction

The model is constructed using Google sketch up [9], the plugins open studio is used to introduce the different variables and to achieve the parametric study.
Energy plus implemented to perform the simulation.

4.3. Modeling process :

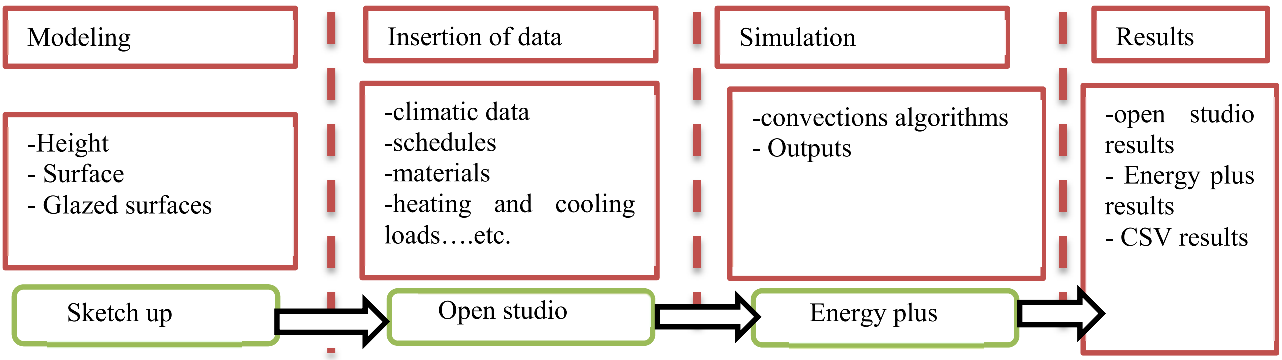


Fig3: Modeling process. Source: Author

5. Methodology

The simulation process has been split into two parts:
The first part consists of simulating case study with openings of different ratios and Single glazing on all orientations: South, North, East and West (the initial case).
The second part represents the optimization process by changing the type of glazing and orientation.

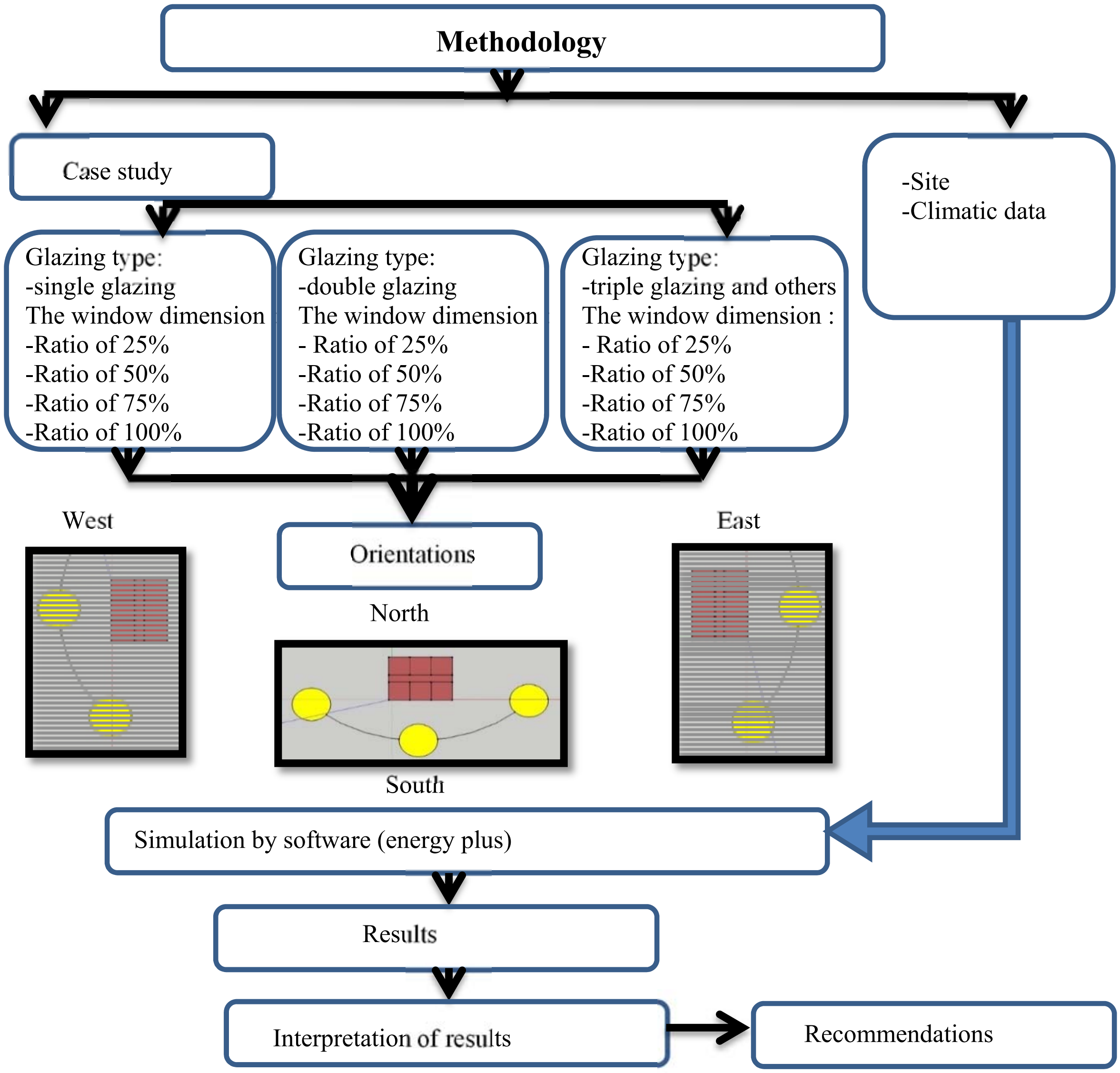
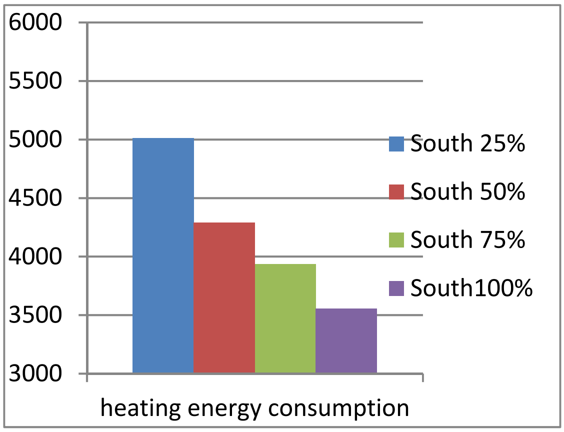


Fig4: simulation process. Source: Author

6. Results and interpretation

6.1. South facing building orientation :

a


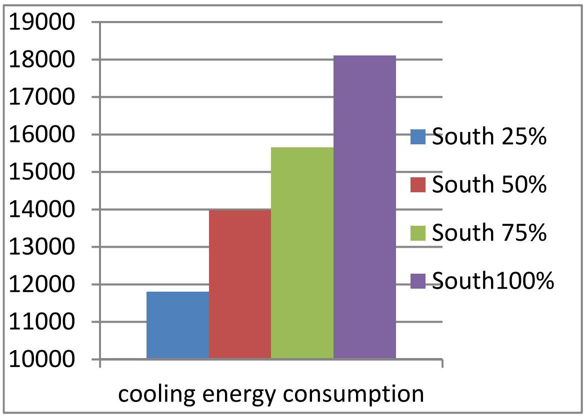
b


Fig5: (a): Heating loads in KWh used according to ratios. Source: Author.
(b) : Cooling loads in KWh according to ratios. Source: Author.

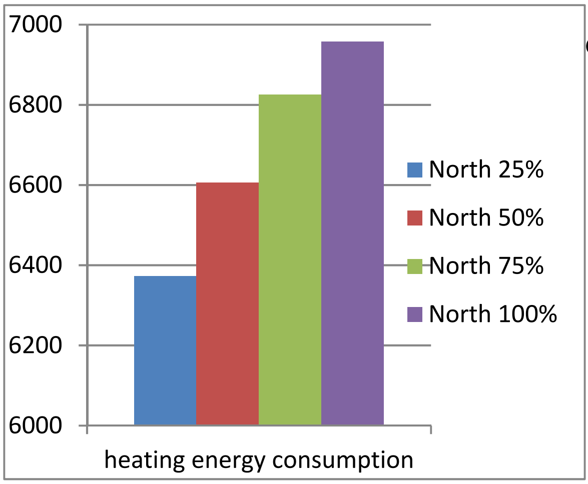
It is clear that the higher energy consumption is in the summer period where there is a significant use of air conditioning system due to long period of overheating (7 months per year from May to November).

Also the cooling load increases linearly with opening ratio and the heating load decreases compared to 25% opening ratio and the results are shown in table 2.

ratio	50%of opening ratio	75%of opening ratio	100%of opening ratio
Heating load	14.3%	21.5%	29.1%
Cooling load	15,6%	24.6%	34.8%

Table 2: Heating and cooling loads according to different ratio compared to 25% opening ratio. (Source: Author).

6.2. North-facing building orientation

c


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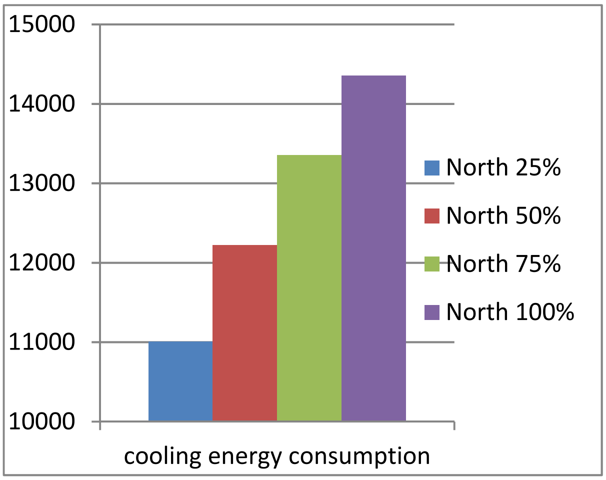


Fig6: (c): Heating loads in KWh according to ratios. Source: Author.
(d) : Cooling loads in KWh according to ratios. Source: Author.

According to the graphs above, the results show that there is a significant increase in cooling and heating loads. and the results are given in table 3.

ratio	50%of opening ratio	75%of opening ratio	100%of opening ratio
Heating load	3.5%	6.6%	8.4%
Cooling load	9.9%	17.6%	23.2 %

Table 3: Heating and cooling loads according to different ratio compared to 25% opening ratio. (Source: Author).

6.3. east-facing building orientation

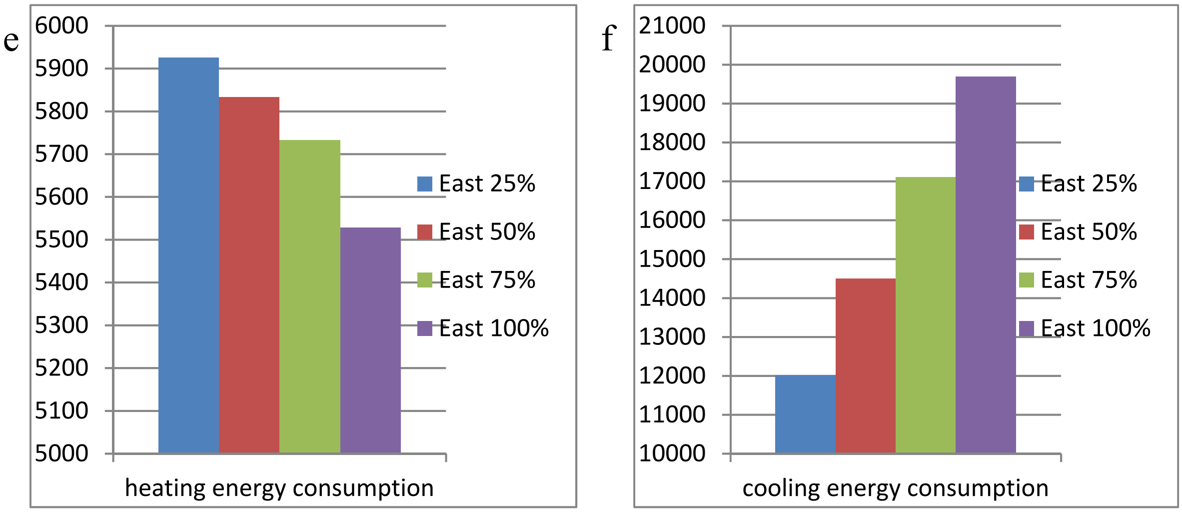


Fig7: (e): Heating loads in KWh according to ratios Source: Author.
(f) Cooling loads in KWh according to ratios. Source: Author.

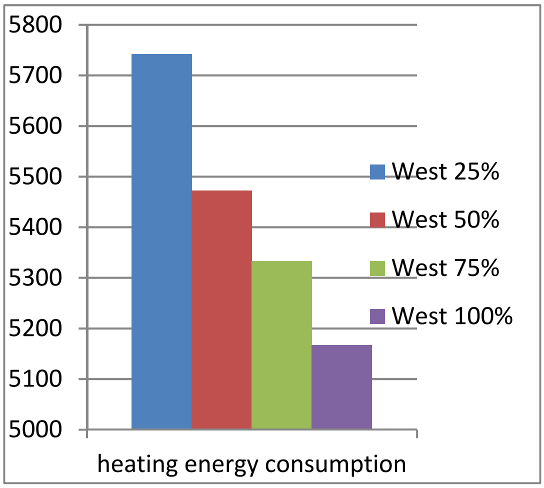
In this case there is a large increase in cooling load; on the other hand, there is a reduction in heating load, and the results are shown in table 4.

ratio	50%of opening ratio	75%of opening ratio	100%of opening ratio
Heating load	1.6%	3.2%	6.3%
Cooling load	17,2%	29.8%	39%

Table 4: Heating and cooling loads according to different ratio compared to 25% opening ratio. (Source: Author).

6.4. The west-facing building

g



h

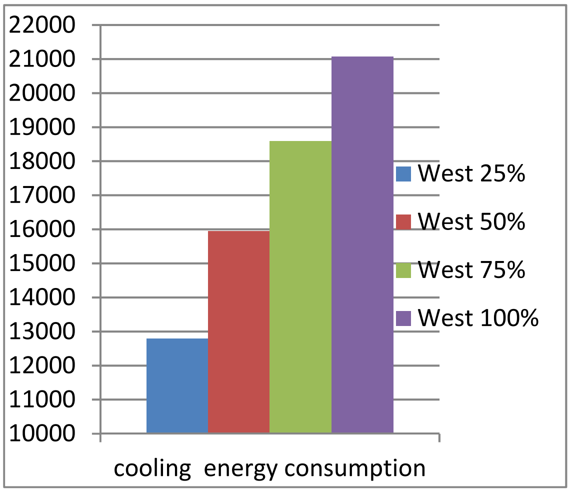


Fig8: (g): Heating loads in KWh according to ratios. Source: Author.
(h): Cooling loads in KWh according to ratios. Source: Author.

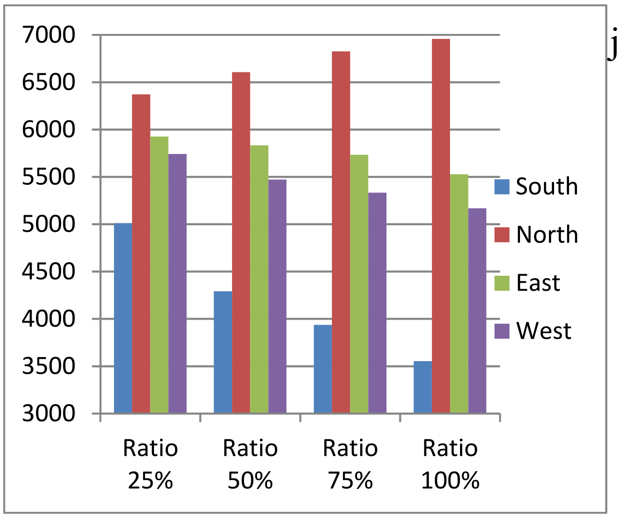
From these graphs it is observed that there is a significant increase in cooling load, on the other side, there is a reduction in heating load. and the results are shown in table 5.

ratio	50%of opening ratio	75%of opening ratio	100%of opening ratio
Heating load	4.7%	7.1%	10%
Cooling load	19.8%	31.8%	39.3%

Table 5: Heating and cooling loads according to different ratio compared to 25% opening ratio. (Source: Author).

6.5. Summary Graphs

i



j

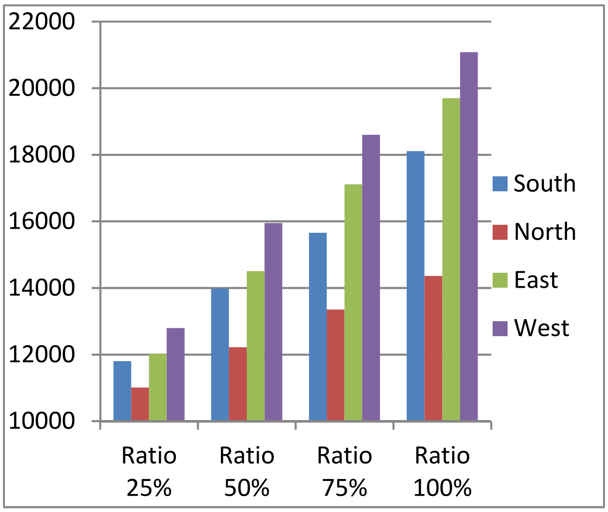
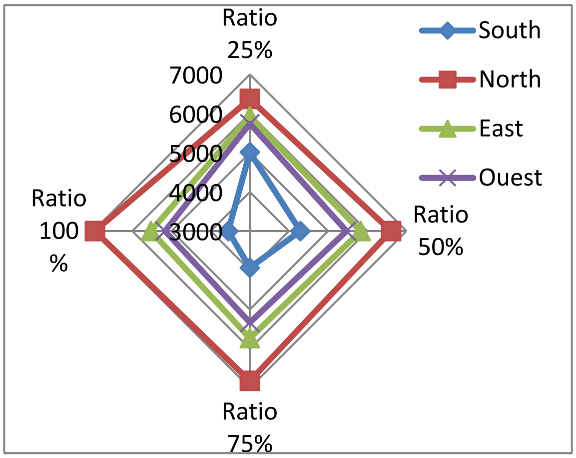


Fig9: (i): Heating loads in KWh according to ratios and orientation. Source: Author.
(j) : Cooling loads in KWh according to ratios and orientation. Source: Author.

k



l

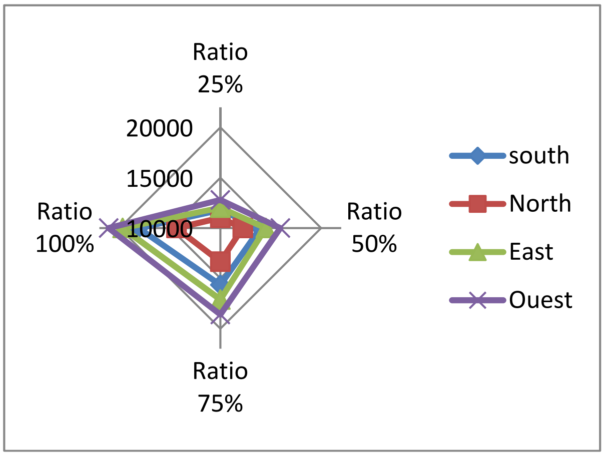


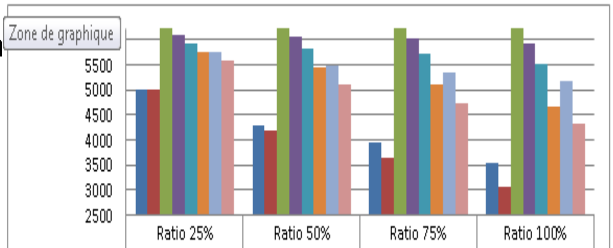
Fig10: (k): Heating loads in KWh according to ratios and orientation. Source: Author.
(l) : Cooling loads in KWh according to ratios and orientation. Source: Author.

It's clear from the overall results that the most favorable oreintation of buildings in this specific areas is the North-South axe orientation and the worst one is East-West axe orientation in term of energy use.

6.6. Optimization of opening ratio and glazing types

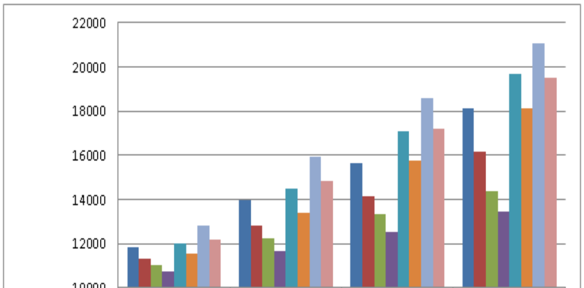
Single glazing / double glazing

m



	Ratio 25%	Ratio 50%	Ratio 75%	Ratio 100%
South	5011	4292	3936	3553
South double	4994	4200	3658	3069
North	6372	6606	6825	6958
North double	6108	6058	6025	5917
East	5925	5833	5733	5528
East double	5742	5439	5103	4678
West	5742	5472	5333	5167
West double	5597	5111	4742	4328

n

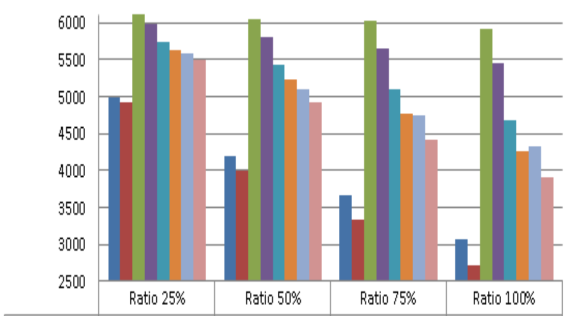


	Ratio 25%	Ratio 50%	Ratio 75%	Ratio 100%
South	11800	13981	15658	18108
South double	11306	12836	14131	16131
North	11008	12219	13353	14358
North double	10753	11661	12519	13417
East	12017	14506	17108	19697
East double	11556	13408	15750	18136
West	12797	15950	18600	21078
West double	12164	14825	17186	19494

Fig11: (m): Heating loads in KWh between single glazing and double glazing. Source : Author.
(n): Cooling loads in KWh between single glazing and double glazing. Source: Author.

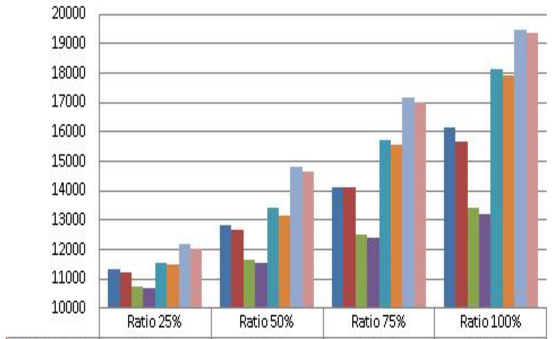
Double glazing /triple glazing

o



	Ratio 25%	Ratio 50%	Ratio 75%	Ratio 100%
South double	4994	4200	3658	3069
South triple	4928	4003	3325	2722
North double	6108	6058	6025	5917
North triple	5994	5814	5664	5461
East double	5742	5439	5103	4678
East triple	5642	5236	4772	4250
West double	5597	5111	4742	4328
West triple	5503	4919	4411	3906

p

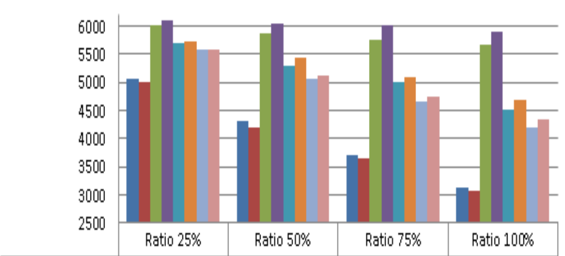


	Ratio 25%	Ratio 50%	Ratio 75%	Ratio 100%
Sud double	11306	12836	14131	16131
Sud triple	11244	12661	14103	15675
Nord double	10753	11661	12519	13417
Nord triple	10703	11567	12406	13203
Est double	11556	13408	15750	18136
Est triple	11469	13175	15536	17947
Ouest double	12164	14825	17186	19494
Ouest triple	12044	14647	17014	19353

Fig12: (o): Heating loads in KWh between double glazing and triple glazing. Source : Author.
(p): Cooling loads in KWh between double glazing and triple glazing. Source: Author.

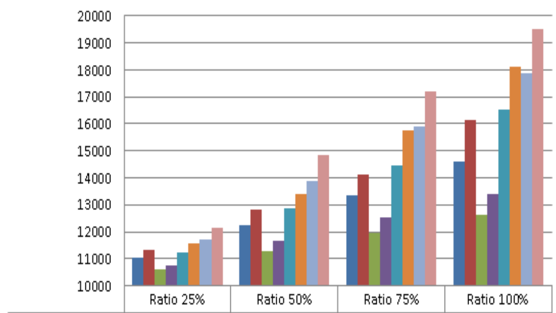
Double glazing / double glazing with low emissivity

q



	Ratio 25%	Ratio 50%	Ratio 75%	Ratio 100%
South double LoE	5075	4300	3697	3122
South double	4994	4200	3658	3069
North double LoE	6022	5878	5753	5664
North double	6108	6058	6025	5917
East double LoE	5711	5311	4997	4525
East double	5742	5439	5103	4678
West double LoE	5594	5078	4650	4192
West double	5597	5111	4742	4328

r



	Ratio 25%	Ratio 50%	Ratio 75%	Ratio 100%
South double LoE	11044	12228	13364	14603
South double	11306	12836	14131	16131
North double LoE	10589	11275	11956	12633
North double	10753	11661	12519	13417
East double LoE	11214	12847	14439	16506
East double	11556	13408	15750	18136
West double LoE	11694	13894	15897	17881
West double	12164	14825	17186	19494

Fig13: (q): Heating loads in KWh between double glazing and double glazing with low emissivity. Source : Author.
(r): Cooling loads in KWh between double glazing and double glazing with low emissivity. Source : Author.

These graphs show that the energy loads for cooling and heating decrease according to glazing type.

7. Conclusion

Results show that the opening ratio, orientation and glazing types have a great impact on the overall energy loads for heating and cooling in buildings under typical climate conditions of the Sahara region.
-The increase in the ratio of openness means the increase in the consumption of total energy.
- The use of double and triple glazing offers a significant reduction in energy consumption.

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